DIAGNOSTIC TEXTURES OF SOME WELDED TUFFS FROM SOUTHEASTERN IDAHO

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Abstract

The rocks of a 250-foot stratified sequence of late Tertiary (Pliocene ?) rhyolitic volcanics in southeastern Idaho show considerable textural variability. Vitroclastic tuffs are associated with lavas and welded tuffs, in both of which there is extensive devitrification. Units of welded tuff have a maximum thickness of 75 feet.

Lavas and welded tuffs are virtually indistinguishable in the field, but in most cases they can be separated on the basis of microtexture.

The welded tuffs are characterized by abundant discrete areas which correspond in size and generalized shape to the shards in neighboring vitroclastic tuffs. Such areas are bounded by rounded rather than cuspate outlines. Glassy areas are usually enclosed by zones of microscopic dust and cryptocrystalline material. Palimpsest glassy areas may be recognized in devitrified welded tuffs by the difference in grain size between these areas and the surrounding matrix. Bands of dust frequently surround devitrified areas.

The glassy lavas often have intricately folded flow bands and perlitic cracks. Elongated vesicles and flow patterns around phenocrysts are common in the lavas and can be recognized in the devitrified flows.

Introduction

Late Tertiary (Pliocene ?) rhyolitic rocks outcrop around the margins of the eastern half of the Snake River Basalt Plain in southeastern Idaho (Kirkham, 1927; Mansfield and Ross, 1935). These rocks are mostly welded tuffs, rhyolites, obsidians, and vitroclastic tuffs.

Acidic volcanics of varied lithologies and textures are well exposed at the southern ends of the Lemhi and Lost River ranges (Fig. 1). In the field, acidic lava is frequently indistinguishable from the welded tuffs. However, microscopic examination of the textures of lavas and welded tuffs often permits these to be distinguished. In addition, a study of these textures and those of vitroclastic tuff suggests some factors important in governing the genesis of welded tuff. A study has been made of specimens from localities A, C, D, E, H, and EB (Fig. 1).

Petrography

Rhyolitic flows. About 5% of both glassy and felsitic lavas are composed of phenocrysts. These phenocrysts are quartz (40%), sanidine (30%), plagioclase (25%), and pyroxene (5%). The quartz phenocrysts often have a stubby bipyramidal form typical of high quartz. In general, quartz and sanidine phe-

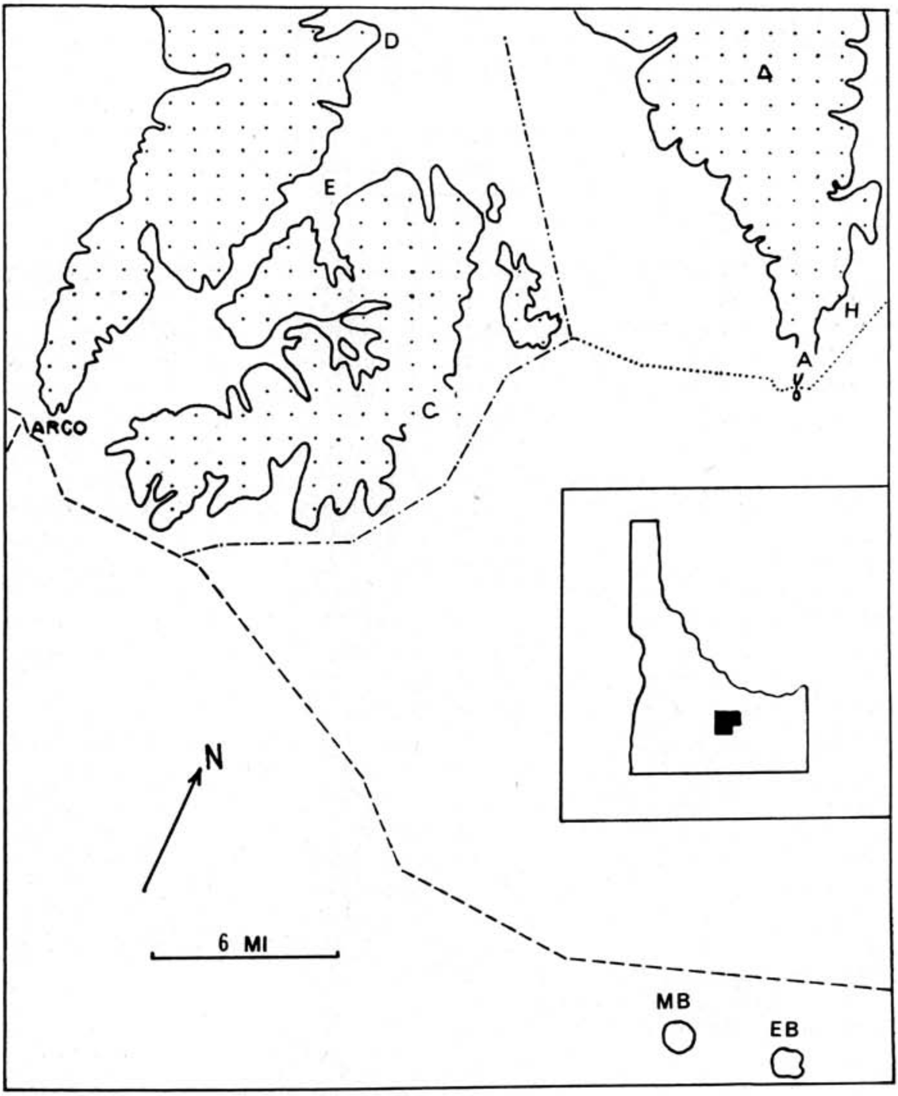

Fig. 1.—Map of study area (blackened area in inset of Idaho). Stippled—Lost River (west) and Lemhi ranges. EB—East Butte. MB—Mid Butte. A, C, D, E, H, EB: areas sampled.

nocrysts are considerably embayed by glass or felsitic groundmass material. Plagioclase and pyroxene phenocrysts are usually not embayed. (Fig. 2a).

Glassy flows, such as the obsidian of Unit 8 (all enumerated rock units refer to the units of the stratigraphic section, Fig. 3 and Table 1) are characterized by highly folded bands of microscopic dust spheres (Fig. 2a). These bands are about 5 mm. long and 0.05 mm. wide and often form wake patterns around phenocrysts. Perlitic cracks, crystallites and spherulites are common.

Felsitic lavas have a groundmass of interlocking potash feldspar and tridymite grains (see section on classification) which have an average diameter of 0.02 mm. Phenocrysts are scattered throughout this groundmass. Although fluidal textures are less distinct in felsitic lavas than in glassy lavas, dust bands which are more finely crystalline than the rest of the groundmass, and elongate vesicles are found and suggest that flow did take place.

Vitroclastic tuff. The vitroclastic tuffs are composed largely of cuspate shards and fragments of pumice cemented by fine carbonate and/or sericite. The average shard size of these tuffs is 0.5-0.8 mm. Individual shards are isotropic, colorless in thin section, and devoid of crystallites. Scattered through this rock are crystals and fragments of quartz, sanidine, and plagioclase. Porosity is characteristically high indicating that little compaction occurred subsequent to formation.

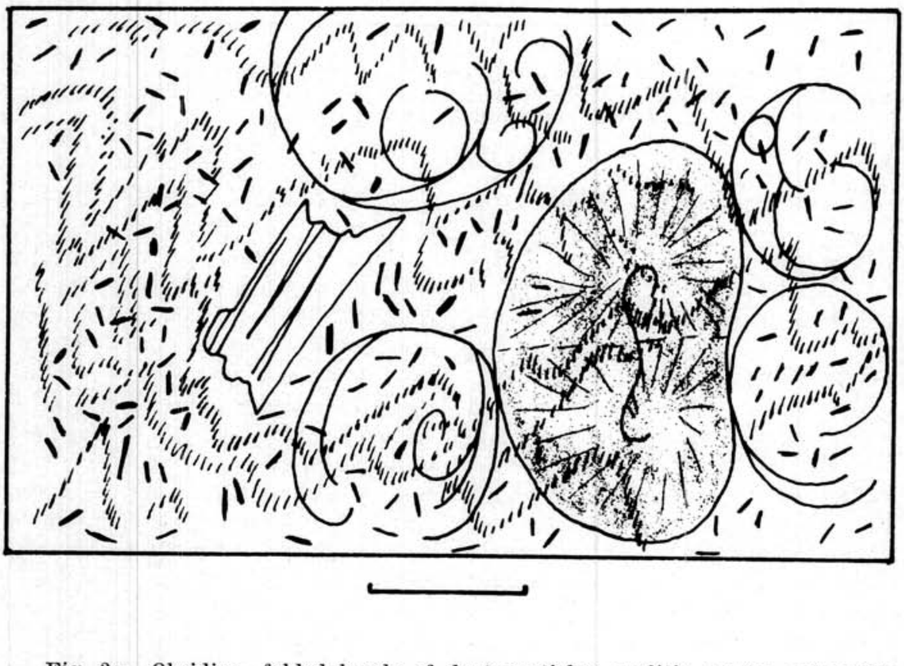

Fig. 2a.—Obsidian, folded bands of dust particles, perlitic cracks, spherulite (Scale = 0.5 mm.).

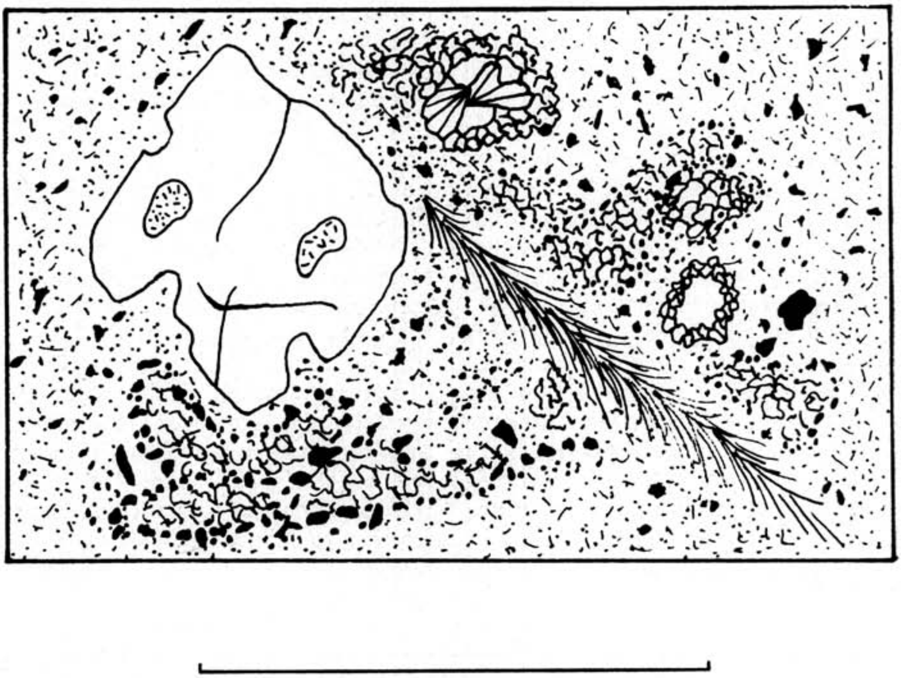

Fig. 2b.—Devitrified welded tuff, embayed quartz (bipyramidal after high quartz), "incipient spherulite", rims of opaque dust outlining devitrified welded shards, wedge-twinned tridymite (Scale = 0.5 mm.).

Welded tuff. Like acidic lava, welded tuff may be either glassy or devitrified.

In the field, glassy welded tuff is virtually indistinguishable from obsidian; both rocks are usually massive and dark colored.

Microscopic examination reveals closely spaced glassy areas of irregular outline and large crystal fragments in a cryptocrystalline matrix containing much microscopic opaque dust (Fig. 2c, 2d). Several features indicate that the glassy areas are molded and welded shards: (1) These areas, averaging 0.3 mm. long and 0.05 mm. wide, are comparable in size to cuspate shards of closely associated vitroclastic tuffs. (2) The shape of areas often suggests modification of originally triangular and cuspate vitroclastic shards. Areas are rounded, mutually interlock, and conform to the outlines of crystal grains. (3) A "bedding-plane" foliation defined by areas suggests that shards were flattened by weight of overburden. (4) Nearly every area has a brown, frequently cryptocrystalline center surrounded by a light yellow isotropic border about 0.005 mm. wide (Fig. 2d). (5) Fine dark, curved, hair-like lines up to 0.01 mm. long, resembling fine fractures, radiate inward from the borders of areas (Fig. 2d). These

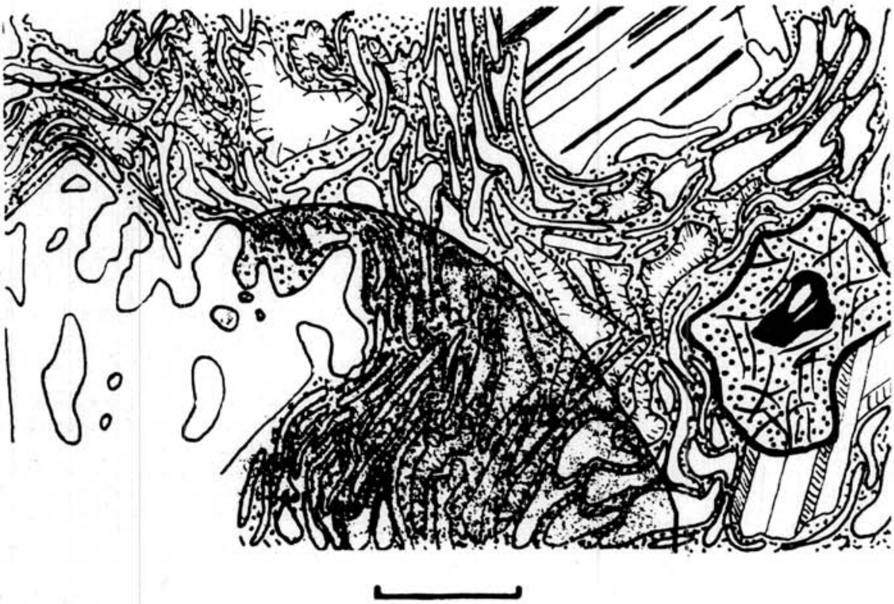

Fig. 2c.—Glassy, welded tuff, embayed quartz, molded shards conforming to one another and to crystal fragments, spherulite (Scale = 0.5 mm.).

lines may be crystallites similar to those noted by Gilbert (1938) in a welded tuff of eastern California. The yellow isotropic borders and hair-like lines (tension fractures ?) suggest that the rims of the shards were chilled. (6) Areas are surrounded by narrow zones of cryptocrystalline matrix containing abundant microscopic opaque dust particles. Both crystallinity and concentration of dust particles in the matrix suggest late stage crystallization, probably caused by the circulation of gases. This matrix apparently welds the molded shards together.

In addition the welded tuff of Unit 4 contains compound spherulites, the sharp boundaries of which cut across individual molded shards which remain discernible in the spherulitic regions (Fig. 2d).

Porosity is variable in glassy welded tuff, fine- to medium-sized vesicles being characteristic.

In the field, devitrified welded tuffs are nearly identical to devitrified rhyolitic lavas; these rocks are usually dense and light colored. Under the microscope, devitrified welded tuff is composed of microcrystalline potash feldspar (70%) and tridymite (20%) and large crystal fragments (10%). Its texture is characterized by areas in which the crystallinity is of a coarser size than surrounding groundmass and which approximate the size and shape of the molded shards of glassy

TABLE 1.—Stratigraphic Section.

Unit #	Thickness ft.	Description
		Top of section, top of slope.
		Perched float: obsidian, brown limy tuff, and dense brown welded tuff.
11	30	Light blue, microcrystalline rhyolite containing sparse phenocrysts of quartz and sanidine and spherical vesicles up to 2cm. in diameter. The rock weathers to a brown massive cliff.
10	65	Light blue, devitrified (fine-grained) welded tuff which contains rare crystal fragments. This rock weathers to a rubbly slope of buff slabs 1-3 in. thick. The upper contact is sharp.
9	13	Light purple, devitrified (very fine-grained) welded tuff containing few slightly embayed crystal fragments. The tuff weathers to a dark brown cliff. The upper contact is gradational.
8	10	Black, perlitic obsidian containing red spherulites and sparse phenocrysts. It weathers to a black exfoliate cliff. The position of the probably sharp upper contact is estimated.
7	3	Mottled gray, firm vitroclastic tuff which contains light, buff angular pumice fragments up to two inches across in a matrix of black shards. It also contains scattered crystal fragments. It weathers massively. The upper contact is sharp.
6	10	Loose, white, limy vitroclastic tuff which is well bedded. It contains poorly sorted fine shards and sparse crystal fragments. The rock weathers to a light, gray debris-covered slope. The upper contact is sharp.
5	65	Very light purple, devitrified (fine-grained) welded tuff containing abundant large crystal fragments of plagioclase, sanidine, and quartz. The rock weathers to 1-3 in. thick slabs which form a loose talus slope. Position of upper contact estimated.
4	10	The basal 4 feet is of dense, medium brown, vitroclastic tuff composed of fine shards. The tuff grades upward into black, glassy, welded tuff containing red spherulites. The rock contains abundant crystal fragments and scattered inclusions of red vitroclastic tuff throughout. The rock weathers to a debris-covered slope. Position of probably gradational upper contact estimated.
3	13	Buff, vitroclastic tuff composed of poorly sorted medium sized shards poorly cemented by calcite grades upward into a firm, red, vitroclastic tuff. Glassy crystal fragments are abundant throughout. The tuff weathers to a non-resistant debris slope.
3	13	The upper contact is sharp.
2	3	Covered interval probably identical to Unit 3.
1	26	Vesicular basalt.
		Base of section is in rubble about 100 feet above valley alluvium.

welded tuff. Such crystalline areas are often crudely outlined by bands of opaque dust particles (Fig. 2b). Furthermore, the outlined areas interlock and conform to crystal fragments. Such areas are interpreted as devitrified molded shards.

The platy Units 5 and 10 have planar zones which are more coarsely crystalline than surrounding areas of groundmass. These zones are parallel to the "bedding" seen in outcrop. Brouwer (1936) considered lamination seen by a variation in

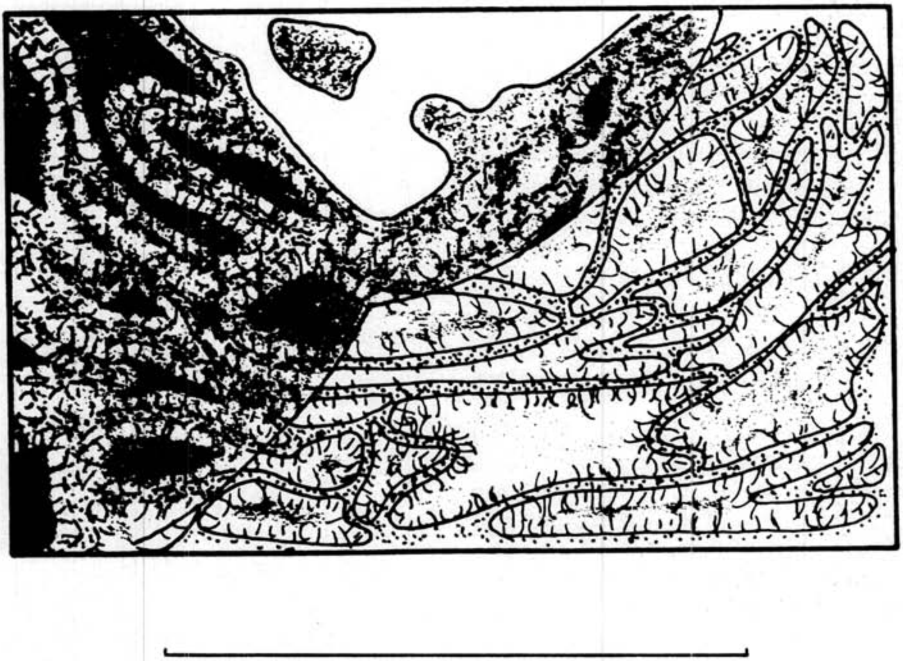

Fig. 2d.—Enlargement of 2c, light borders around glassy molded shards, hair-like lines on shards, interstitial opaque dust, compound spherulite (Scale = 0.5 mm.).

grain size in acidic rocks of Yellowstone National Park to have been caused by increased friction due to late stage liquid movement, or by the circulation of gases liberated along planes of movement. However, vertical compression of a porous and perhaps initially stratified mass might also produce zones concentrated with volatiles.

Feather-shaped aggregates of microlitic needles occur in Unit 9 (Fig. 2b). These aggregates are subparallel at an angle of about 20° to the elongation of devitrified molded shards. The aggregates seem to be incipient spherulites.

Devitrified welded tuffs contain spherical vesicles which are similar to those of glassy welded tuffs, but which have more ragged outlines due to the crystallinity of the surrounding groundmass (Fig. 2b).

Welded tuffs frequently contain clay minerals and/or carbonate. In many cases these minerals are closely associated with vesicles and cracks, suggesting that they may have been formed by weathering. However, in other cases they are more or less evenly distributed throughout the groundmass and possibly have resulted from devitrification aided by volatiles.

The crystals and crystal fragments contained in glassy and devitrified welded tuff are similar in composition, degree of embayment and abundance to the phenocrysts found in associated rhyolitic lavas. Since neither their nature nor their occurrence can be related to extrusive processes, these grains clearly have had an intratelluric origin.

Genesis, Classification and Age of Volcanic Rocks

Genesis (welding). Gilbert (1938) has shown that the degree of consolidation and welding of the Bishop Tuff of eastern California is a function of the thickness of overburden. Fenner (1937) noted that the amount of welding may also be related to proximity to source area.

The base of Unit 4 is a hard, dense yellow vitroclastic tuff. Its cuspate shards have brown centers, which in some cases are cryptocrystalline, and light yellow rims. The shards are surrounded by a cryptocrystalline matrix abounding in microscopic dust. The underlying unit is baked or weathered red at its top. These relationships strongly suggest that the base of Unit 4, which grades upward into welded tuff, was chilled and welding thereby prevented. Therefore, rate of cooling may also be a fundamental factor controlling welding.

Several intensities of welding are represented in the microtextures of the welded tuffs examined in this study. Low degrees of welding are suggested by textures barely distinguishable from those of vitroclastic tuffs, whereas textures similar to those of acidic lavas seem to indicate more complete welding. Welding apparently begins with slight rounding of cuspate shards, followed by gross deformation and rounding of shards accompanied by decrease in porosity.

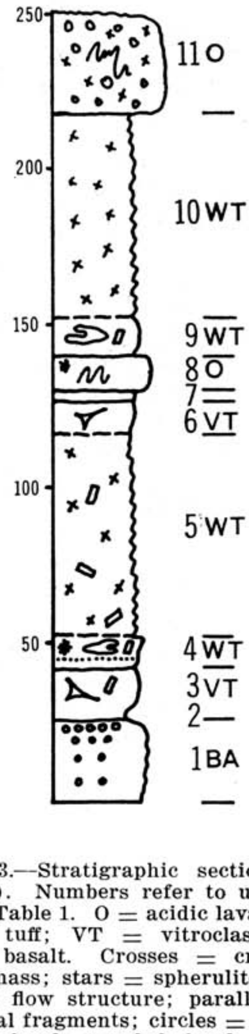

Fig. 3.—Stratigraphic section at A (Fig. 1). Numbers refer to unit numbers of Table 1. O = acidic lava; WT = welded tuff; VT = vitroclastic tuff; BA = basalt. Crosses = crystalline groundmass; stars = spherulites; wavy lines = flow structure; parallelograms = crystal fragments; circles = vesicles; cuspate shard; rounded shard = welded shard; solid line = sharp contact; dashed line = gradational contact.

Devitrification of welded tuffs seems to represent the most intense stage of welding. Since glassy and devitrified welded tuffs occur within a few vertical feet of one another in the stratigraphic section (Fig. 3), devitrification probably took place before the rock had cooled to air temperature. In other words, if devitrification had been caused by some factor not related to the environment of formation (such as age or intensity of later folding), no glassy rocks would be expected in any of the tabulated section. Therefore, devitrification may here be considered a part of the welding process. In Units 4 and 5, where a chilled basal zone of vitroclastic tuff grades upward first into glassy welded tuff and finally into devitrified welded tuff, devitrification seems to be a final intense stage of welding.

Genesis (formation). Mansfield and Ross (1935) considered the welded tuffs of southeastern Idaho to have been formed by extrusive processes similar to those described by Fenner (1920, 1923) for the Great Tuff Flow of the Valley of Ten Thousand Smokes in Alaska. Since the rocks of this study are very similar to those described by Mansfield and Ross, Fenner's description (1920, p. 581) is appropriate. He states that "rhyolitic magma, charged with dissolved gases, rose to the surface in the newly formed vents. According to general observation the usual course for such a magma is either to retain its gases and form a flow of obsidian, or to evolve them with explosive violence and scatter the disrupted particles to a great distance. In this instance, however, it apparently pursued an intermediate course, and produced, by moderately forcible disruption, an outward-spreading and forward-moving torrent of incandescent sand and pumice, each particle of which was surrounded by and partially suspended in gases which it continued to give forth during its impetuous flow."

The welded tuffs of this study (like those described by Mansfield and Ross, 1935) are thin in comparison with both the Tuff Flow of the Valley of Ten Thousand Smokes (100+ feet thick, Fenner, 1920) and the Bishop Tuff of eastern California (300+ feet thick, Gilbert, 1938). Units 4 and 5 have a total thickness of 75 feet. They seem to be the lower welded part of one such tuff deposit, its overlying vitroclastic tuff having been eroded.

Classification. Megascopically the crystalline rocks of the present study are felsites. Microtextures reveal that many of the felsites are welded tuffs, a few are lavas, although several remain of doubtful origin.

Another useful parameter of classification is mineralogical composition. Mansfield and Ross (1935) stated that the finely crystalline matrix of welded tuffs south of the Snake River Plain is probably composed of feldspar and tridymite. Gilbert (1938) states that the crystallization products of vitric fragments in a welded tuff of eastern California are potassic feldspar and tridymite.

Fenner (1936) and Terzaghi (1948) related devitrification to hot gases and concluded that it is accompanied by a bulk increase in potash and silica.

The present study reveals that the microcrystalline groundmass of both welded tuffs and fluidal rocks contains two major minerals. The more abundant has a refractive index slightly less than that of balsam and birefringence of about 0.006. It is probably sanidine. The less abundant mineral has a refractive index considerably less than balsam, a birefringence of about 0.003, and occasionally displays wedge-like twinning characteristic of tridymite. Since plagioclase occurs only as a phenocrystic constituent, the predominant feldspar is potassic, and the felsitic rocks here investigated are consequently rhyolitic.

Furthermore, the indices of refraction of glass shards from Units 3 and 4 and the upper welded tuff of Six Mile Canyon (area C on Fig. 1) are 1.499± 0.003 in all three cases. According to data presented by Heinrich (1956, p. 39), such a refractive index is in the range of glasses having an acidic or intermediate composition.

Age. Regional correlation of volcanics having scattered source areas is difficult. In the absence of sedimentary marker beds or fossil evidence, lithologic similarity within a limited petrographic province must be assumed to indicate roughly contemporaneous formation.

On the basis of lithology, Kirkham (1927) concluded that the rocks described in Table 1 are the westernmost occurrence of Tertiary Late Lavas (Pliocene ?).

Other formations which are lithologically similar and probably time-equivalent to the Tertiary Late Lavas of the tabulated section are the Eagle Rock Tuff (Pliocene ?) of southeast Idaho (Stearns *et al.*, 1938) and the Eddie School Rhyolites (Pliocene ?) of southwestern Montana and adjacent Idaho (Scholten *et al.*, 1955).

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